An increase of 19.8 percent in the number of housing units was observed between 1970 and 1980 in Ashtabula County (see Table 4-16). Increases in housing units for the City of Ashtabula were considerably less, at 1.6 percent. Ashtabula Township had an increase of 17.6 percent in housing units during the same time period.

4.6.2 Land Use

4.6.2.1 Land Use in Vicinity of the RMI Site. In order to determine land uses in the vicinity of the RMI site, a survey of surrounding areas was conducted in January 1989. In addition, historical aerial photos were reviewed.

The RMI Sodium Plant is located in a highly industrialized area of Ashtabula County. Other local industries include Occidental Chemical Corporation, Vygen Corporation, Elkem Metals, RMI Extrusion, RMI Metals, Detrex Industries, Acme Scrap and Metal, and SCM (Figure 4-24).
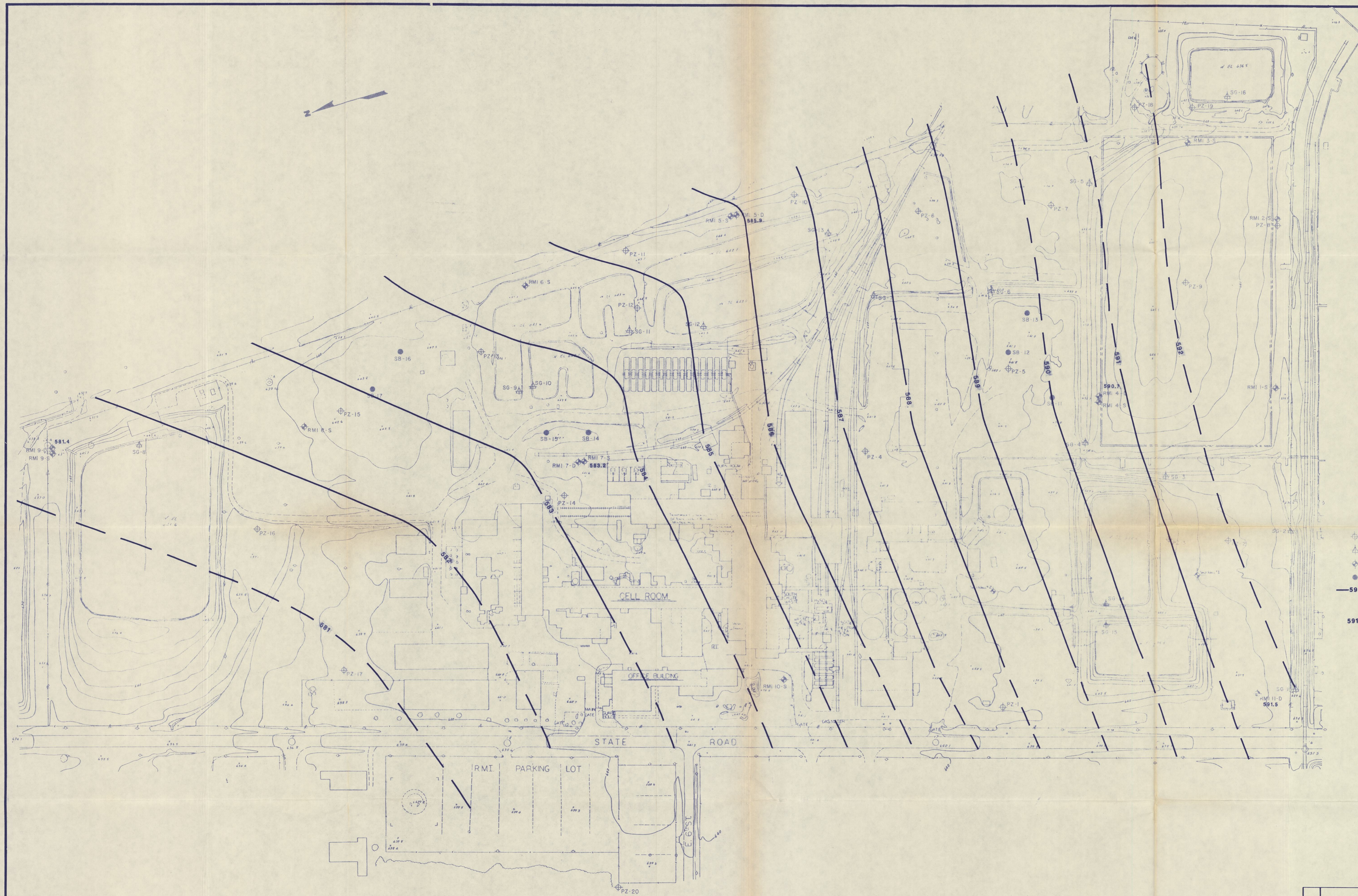
The Detrex facility is located on the southern border of the RMI Sodium Plant. Detrex manufactures muriatic acid through contact of water with chlorine gas. Detrex has previously manufactured N-methylpyrole and chlorinated solvents. The wastes from the manufacture of the solvents were kept in on site lagoons. The lagoons were emptied and refilled with clay in 1977. During a RCRA reconnaissance inspection in 1980, unidentified drums and an open waste mound were found. Hexachlorobutane was found to be the primary constituent of the waste mound (USEPA, 1985).

To the east of the facility, the Elkem Metals complex is in operation. The complex includes a gas plant, a welding products plant, and ferroalloy plant. The gas plant refines specialty gases from purified air. The welding products plant manufactures welding rod and wire utilizing a variety of cleaning agents and flux materials such as potassium permanganate, caustic soda, sulfuric acid, muriatic acid, copper, sulfate, borax, nickel, and chromium. Wastewaters from the ferroalloy plant are derived largely from fume cleaning

TABLE 4-16

HOUSING INFORMATION

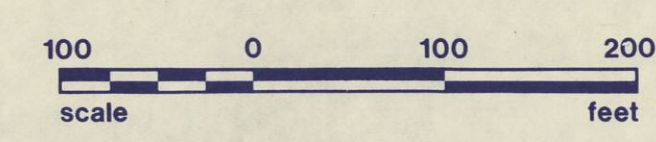| Total Housing Units	Ashtabula County	Ashtabula City	Ashtabula Township
1970	33,835	7,925	2,404
1980	40,528	9,159	2,827
Percent Change	+19.8	+1.6	+17.6

Source: Ashtabula County Planning Commission, 1980.

LEGEND:
⊕ PIEZOMETER
△ STREAM GAUGE
⬦ MONITORING WELL
● SOIL BORING

—592— GENERALIZED STRUCTURE CONTOUR, IN FEET, CONTOUR INTERVAL IS ONE FOOT, DASHED WHERE INFERRED

591.5 OBSERVED ELEVATION OF THE TOP OF BEDROCK, IN FEET MSL

CELL ROOM

OFFICE BUILDING

STATE ROAD

RMI PARKING LOT

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-10
STRUCTURE CONTOUR MAP, TOP OF SHALE

SCALE: 1" = 100'

100 0 100 200
scale   feet

NO.	REVISIONS	REV'D BY	DATE	APPRO'D BY

DRAWN BY	DATE	CHECKED BY	APPROVED BY	DRAWING NUMBER

LEGEND:
- PIEZOMETER
- STREAM GAUGE
- MONITORING WELL
- SOIL BORING
→ GROUNDWATER FLOW DIRECTION

CELL ROOM

OFFICE BUILDING

STATE ROAD

R.M.I. PARKING LOT

E. 6" ST.

100   0   100   200
scale   feet

SCALE: 1" = 100'

NO.	REVISIONS	REV'D BY	DATE	APPRO'D BY

AWARE
INCORPORATED

NASHVILLE, TENNESSEE
MAHWAH, NEW JERSEY

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-11
WATER TABLE SURFACE MAP,
JANUARY 10, 1989

DRAWN BY   DATE   CHECKED BY   APPROVED BY   DRAWING NUMBER

LEGEND:

⦿ MANHOLE
● CATCH BASIN
⊕ SURFACE DRAIN
→ DIRECTION OF SURFACE WATER FLOW

CELL ROOM

OFFICE BUILDING

STATE ROOM

RMI PARKING LOT

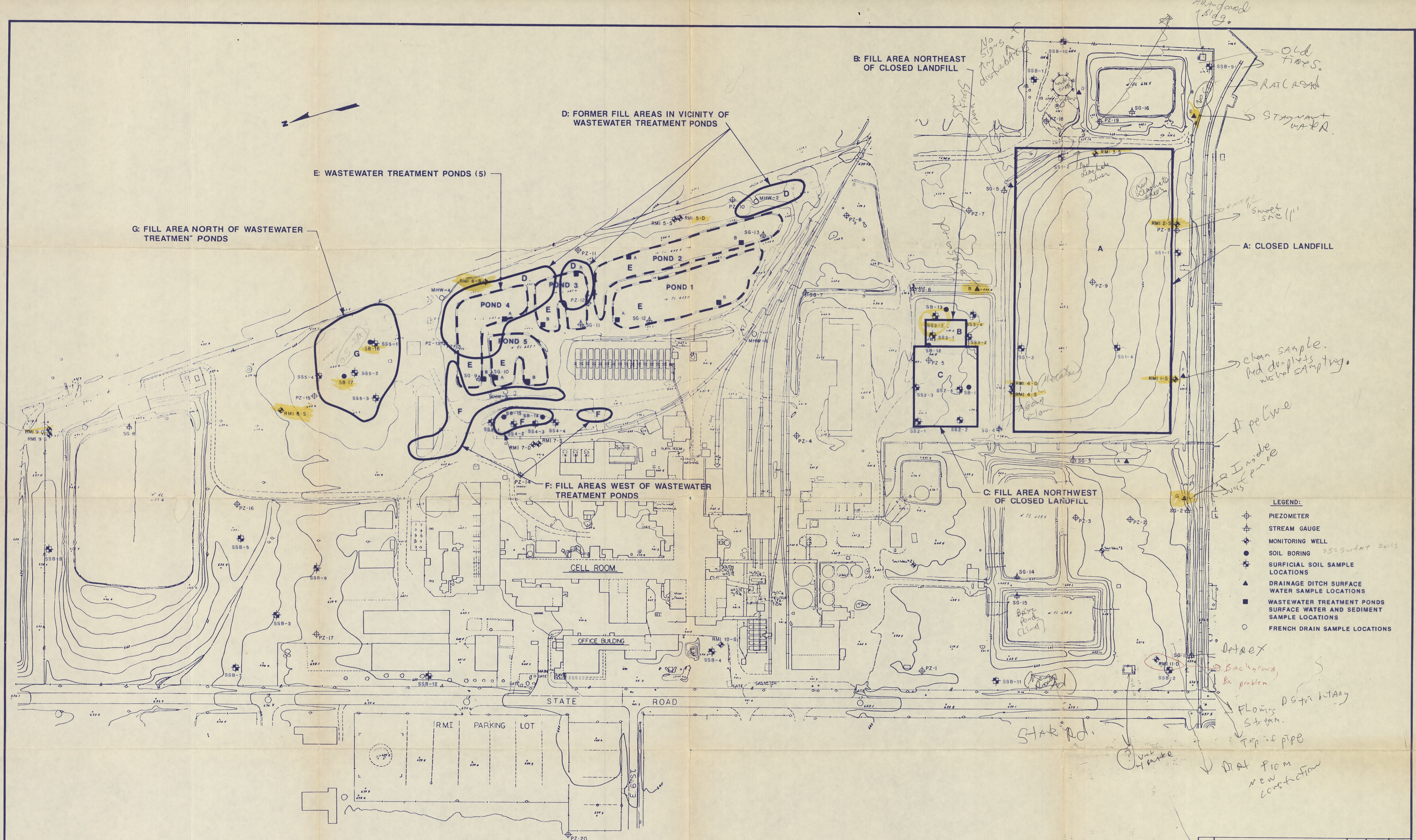E. 20TH ST.

48" STORM SEWER

RMISP
TOPOGRAPHICAL MAP
B-2-A

AWARE INCORPORATED
NASHVILLE, TENNESSEE
MAHWAH, NEW JERSEY

RMI SODIUM PLANT
ASHTABULA, OHIO

FIGURE 4-23

SITE SURFACE WATER
DRAINAGE PATTERNS

LAKE ERIE

LAKE ERIE

RMI SODIUM PLANT

LEGEND:
✦ WELL

WELL LOCATION INFORMATION SOURCE: OHIO DEPARTMENT
OF NATURAL RESOURCES, FEBRUARY, 1989.

SOURCE: USGS 7 1/2 MINUTE QUADRANGLE MAPS: NORTH
KINGSVILLE, OHIO (1979); ASHTABULA NORTH, OHIO (1970);
ASHTABULA SOUTH, OHIO (1970); AND GAGEVILLE, OHIO (1979).

AWARE INCORPORATED   NASHVILLE, TENNESSEE
MAHWAH, NEW JERSEY

RMI SODIUM PLANT
ASHTABULA, OHIO

FIGURE 4-5

SURFACE WATER PATTERNS AND WELL
LOCATIONS IN THE VICINITY OF
RMI SODIUM PLANT

B: FILL AREA NORTHEAST OF CLOSED LANDFILL

D: FORMER FILL AREAS IN VICINITY OF WASTEWATER TREATMENT PONDS

E: WASTEWATER TREATMENT PONDS (5)

G: FILL AREA NORTH OF WASTEWATER TREATMENT PONDS

A: CLOSED LANDFILL

C: FILL AREA NORTHWEST OF CLOSED LANDFILL

F: FILL AREAS WEST OF WASTEWATER TREATMENT PONDS

POND 1
POND 2
POND 3
POND 4
POND 5

CELL ROOM

OFFICE BUILDING

STATE ROAD

RMI PARKING LOT

LEGEND:
- PIEZOMETER
- STREAM GAUGE
- MONITORING WELL
- SOIL BORING
- SURFICIAL SOIL SAMPLE LOCATIONS
- DRAINAGE DITCH SURFACE WATER SAMPLE LOCATIONS
- WASTEWATER TREATMENT PONDS SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS
- FRENCH DRAIN SAMPLE LOCATIONS

NO. | REVISIONS | REV'D BY | DATE | APPRO'D BY

SCALE: 1" = 100'
DRAWN BY | DATE | CHECKED BY | APPROVED BY | DRAWING NUMBER

100 0 100 200
scale   feet

CELL ROOM

OFFICE BUILDING

STATE ROAD

RMI PARKING LOT

AWARE
INCORPORATED

NASHVILLE, TENNESSEE
MAHWAH, NEW JERSEY

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-6

LOCATIONS OF GEOLOGIC CROSS SECTIONS

SCALE: 1" = 100'

100   0   100   200
scale   feet

NO.	REVISIONS	REV'D BY	DATE	APPRO'D BY

DRAWN BY	DATE	CHECKED BY	APPROVED BY	DRAWING NUMBER

N

CELL ROOM

OFFICE BUILDING

STATE ROAD

RMI PARKING LOT

LEGEND:

⊕ PIEZOMETER

△ STREAM GAUGE

⊕ MONITORING WELL

● SOIL BORING

—592— GENERALIZED STRUCTURE CONTOUR, IN FEET, CONTOUR INTERVAL IS ONE FOOT, DASHED WHERE INFERRED

591.5 OBSERVED ELEVATION OF THE TOP OF BEDROCK, IN FEET MSL

100	0	100	200
scale			feet

SCALE: 1" = 100'

DRAWN BY	DATE	CHECKED BY	APPROVED BY

AWARE INCORPORATED

NASHVILLE, TENNESSEE
MAHWAH, NEW JERSEY

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-10
STRUCTURE CONTOUR MAP, TOP OF SHALE

NO.	REVISIONS	REV'D BY	DATE	APPRO'D BY

DRAWING NUMBER

LEGEND:
⊕ PIEZOMETER
⚲ STREAM GAUGE
⌖ MONITORING WELL
● SOIL BORING
→ GROUNDWATER FLOW DIRECTION

NOTE: A schematic of the french drain system is shown in figure 3-2. Site surface water drainage patterns are shown in figure 4-23.

CELL ROOM

STATE ROAD

RMI PARKING LOT

OFFICE BUILDING

RMI SODIUM PLANT
Ashtabula, Ohio

NASHVILLE, TENNESSEE
MAHWAH, NEW JERSEY

AWARE
INCORPORATED

FIGURE 4-11
WATER TABLE SURFACE MAP,
JANUARY 10, 1989

SCALE: 1" = 100'

100   0   100   200
scale   feet

NO.	REVISIONS	REV'D BY	DATE	APPROD BY

DRAWN BY	DATE	CHECKED BY	APPROVED BY		DRAWING NUMBER

CELL ROOM

OFFICE BUILDING

STATE ROAD

RMI PARKING LOT

48" STORM SEWER

LEGEND:

⊕ MANHOLE
● CATCH BASIN
⊕ SURFACE DRAIN
→ DIRECTION OF
   SURFACE WATER
   FLOW

Denotes Closed Landfill
For Details See R.MI
Dwg's 14-1020
14-1021
14-1022

RMISP
TOPOGRAPHICAL MAP
B-2-A

AWARE
INCORPORATED

NASHVILLE, TENNESSEE
MAHWAH, NEW JERSEY

RMI SODIUM PLANT
ASHTABULA, OHIO

FIGURE 4-23

SITE SURFACE WATER
DRAINAGE PATTERNS

A'

650

9-D
9-S
FILL
8-S
7-D
7-S
4-D
4-S
SB-11
CLAY CAP
1-S
FILL
FILL
FILL
FILL
640
WEATHERED GLACIAL TILL
WEATHERED GLACIAL TILL
630
SANDY TILL
GLACIAL TILL
SANDY TILL
620
GLACIAL TILL
610
600
590
CHAGRIN SHALE
580

200   0   200   400

scale   feet
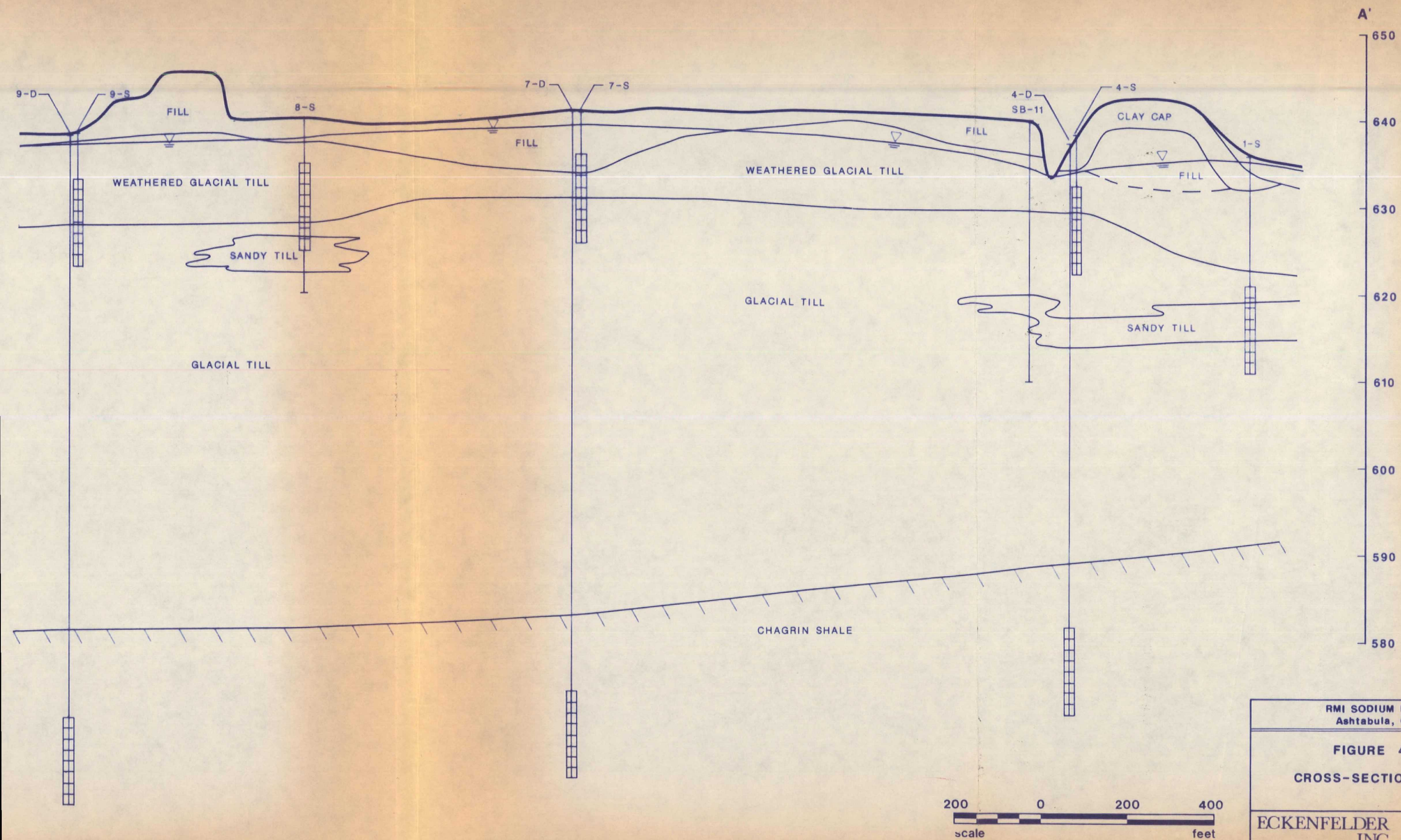
RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-7

CROSS-SECTION A-A'

ECKENFELDER   Nashville, Tennessee
INC.   Mahwah, New Jersey

4-11

CROSS-SECTION B-B' — Figure 4-8

Labels visible in figure:

B'

9-S · SB-16 · 6-S · 5-D · 5-S · 3-S · CLAY CAP · 2-S

FILL

WEATHERED GLACIAL TILL

GLACIAL TILL

GLACIAL TILL

GLACIAL TILL

GLACIAL TILL

WEATHERED GLACIAL TILL

SANDY TILL

SANDY TILL

CHAGRIN SHALE

Elevation scale (right side): 650, 640, 630, 620, 610, 600, 590, 580

Scale: 200 0 200 400 feet

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-8

CROSS-SECTION B-B'

ECKENFELDER INC.   Nashville, Tennessee
Mahwah, New Jersey

CROSS-SECTION C-C'

and include cyanide and phenolic wastestreams. Wastewaters are treated and discharged to Lake Erie and most of the currently active site drains north to Lake Erie. However, some of the older lagoons for on site storage of sludges may be in the Fields Brook drainage basin (USEPA, 1985).

Ray Roofing and Occidental Chemical Corporation are located along the western boundary of the RMI facility. The processes used or products manufactured by these facilities are unknown. Three coal fired power plants are located to the north and east of the RMI facility.

4.6.2.2 **County Land Use.** The major residential areas of Ashtabula County are located along Lake Erie in the areas of Ashtabula City, Kingsville, and Conneaut City. South of Interstate 90, the County is rural in character with the population dispersed among small farms and villages. Only about 4 percent of the County is designated as residential. Production and commercial land uses in the County are centered mainly in Ashtabula City and Conneaut City. These uses account for about 1 percent of the land use in Ashtabula County (Dames & Moore, 1987).

Farms and registered forests occupy 42 percent of Ashtabula County's land area. Ashtabula County has lost 64 percent of its farms since 1949. Although the number of farms has been dramatically reduced, the remaining farms have been increasing in size. In 1949, the average farm size was 86 acres, while in 1978, it was 142 acres (Dames & Moore, 1987).

There are many recreational areas scattered throughout the County. Several of the larger areas are located near Geneva on the Lake, Rock Creek Village and Pymatuning Reservoir. There are several other small areas located along Lake Erie.

All or portions of the following contiguous townships are located within three miles of the RMI site:

- Saybrook
- Ashtabula
- Plymouth
- Kingsville
- Sheffield

The aggregate area of these townships is about 72,500 acres, or approximately 16 percent of all of Ashtabula County. The pattern of land use within the three-mile radius is similar to that of the overall county; however, the effects of urbanization can be seen in increased land use for industrial, commercial, and residential activities (Dames & Moore, 1987). General land use categories within approximately three miles of the RMI site are given in Table 4-17.

TABLE 4-17

GENERAL LAND USE WITHIN THREE
MILES OF THE RMI
SODIUM PLANT

Land Use	Percent
Unclassified (including vacant land)	55
Farming	21
Residential	8
Registered forest	7
Public land, water, roads	6
Industrial	2
Commercial	1

Source: Dames & Moore (1987), from the Ashtabula County Planning Commission, 1980.

LAKE ERIE

RMI SODIUM PLANT

WALNUT BEACH PARK

East Ashtabula

ASHTABULA

ASHTABULA

ASHTABULA RIVER

ASHTABULA

LEGEND

WELL (Withdraw Water From Chagrin Shale)

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-20

MAP SHOWING BOUNDARY OF
CRA AND WELL LOCATIONS

ECKENFELDER INC.

Nashville, Tennessee
Mahwah, New Jersey

SOURCE: USGS 7 1/2 MINUTE QUADRANGLE MAPS: NORTH
KINGSVILLE, OHIO (1979); ASHTABULA NORTH, OHIO (1970);
ASHTABULA SOUTH, OHIO (1970); AND GAGEVILLE, OHIO (1979).

ERIE

LAKE

ERIE

-N-

RMI SODIUM
PLANT SITE

531

531

11

ASHTABULA RIVER

East Ashtabula

FIELDS
BROOK

ASHTABULA

LEGEND

At   : Atherton Silt Loam
BrB, BrC2: Braceville Loam
Cd   : Canadice Soils, Mucky Variants
ClB   : Chenango Gravelly Loam
CmB   : Claverack Loamy Fine Sand
Ct   : Conneaut Silt Loam
ElB   : Elnora Loamy Fine Sand
Hm   : Holly Silt Loam
Kf   : Kingsville Fine Sandy Loam
Ma   : Made Land
PoD2: Pierpont and Platea Soils
PsB, PsC: Platea Silt Loam
RhB   : Red Hook Silt Loam
Sm   : Steep Land, Loamy
Sw   : Swanton Fine Sandy Loam,
        Silty Subsoil Variant

w   : Water

0   1000'   2000'

Scale   Feet
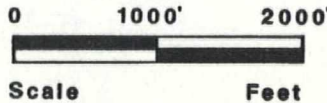
SOURCE: U.S. SOIL CONSERVATION SERVICE, 1973

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-21

SOIL PATTERNS IN THE VICINITY
OF THE RMI SODIUM PLANT

ECKENFELDER   Nashville, Tennessee
INC.   Mahwah, New Jersey

4-50

RMI SODIUM PLANT

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-24

LAND USE MAP
IN VICINITY OF THE
RMI SODIUM PLANT

AWARE
INCORPORATED

NASHVILLE, TENNESSEE
MAHWAH, NEW JERSEY

RMI SODIUM PLANT
Ashtabula, Ohio

FIGURE 4-24

LAND USE MAP IN VICINITY
OF THE RMI SODIUM PLANT

ECKENFELDER INC.   Nashville, Tennessee
Mahwah, New Jersey

4-70
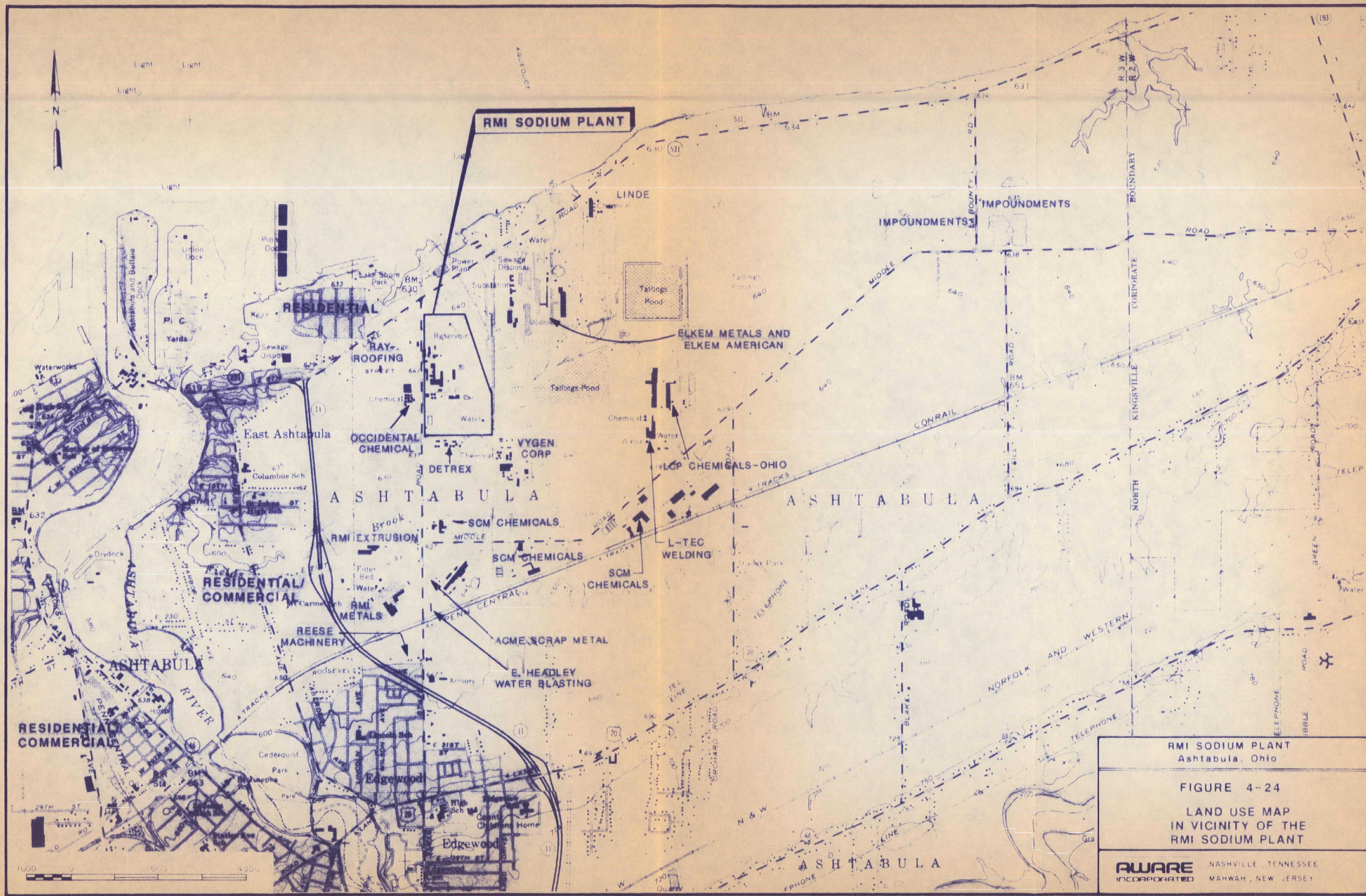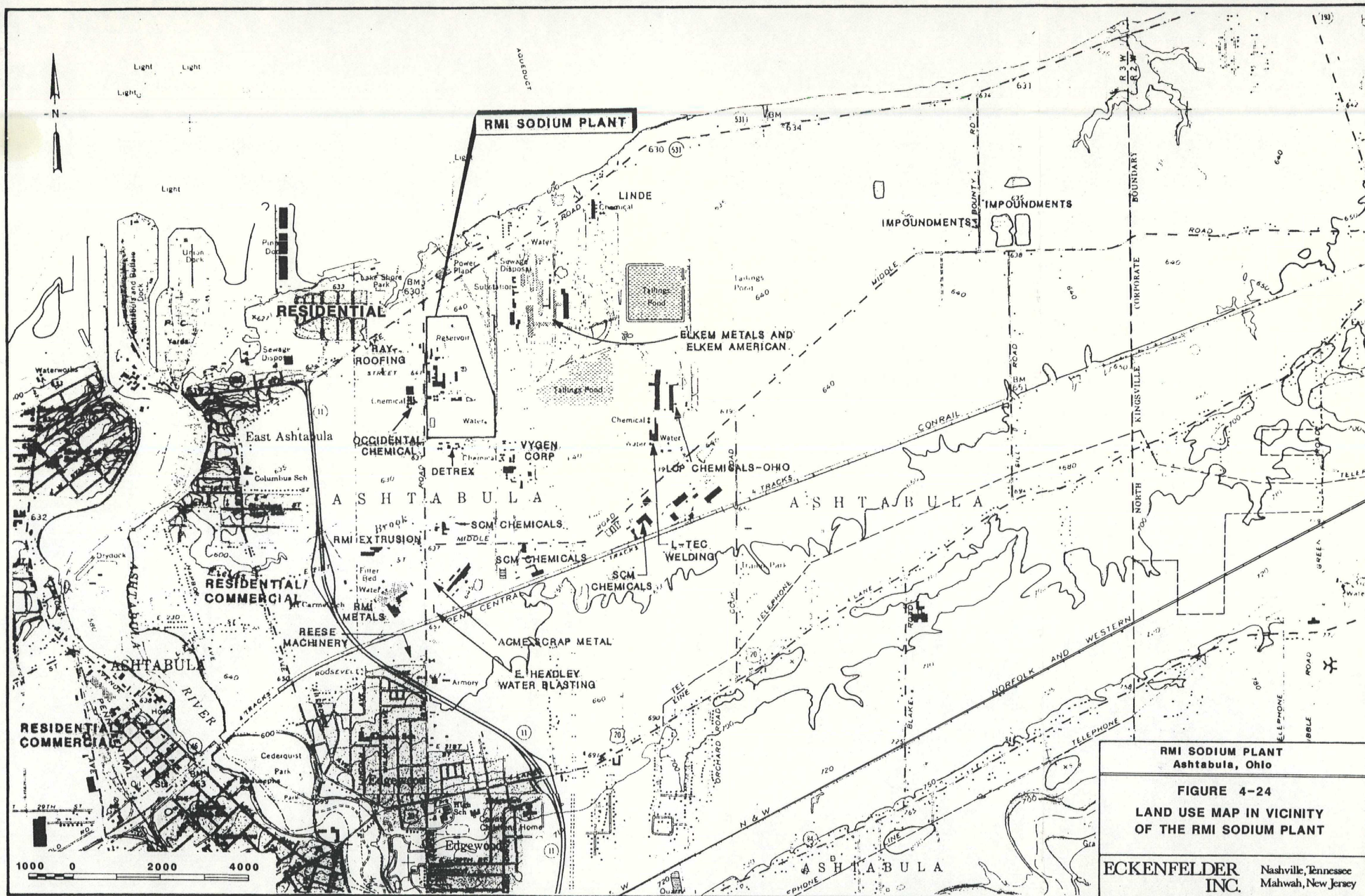
5.0   SOURCE CHARACTERIZATION

5.1   IDENTIFICATION OF SWMU's

RMI's RCRA hazardous waste management operating permit for the Sodium Plant identifies five (5) solid waste management units (SWMUs).   However, the revised "Certification Regarding Potential Releases From Solid Waste Management Units", transmitted to USEPA and Ohio EPA in late September 1986, identifies additional potential SWMUs.   Ten SWMUs are currently identified at the Sodium Plant and are listed in Table 5-1.

5.2   UNIT CHARACTERIZATION

Of the ten previous and active SWMU's identified in Table 5-1, seven were included in the RFI.   Waste management activities at the south chute waste pile and burning room are regulated through the provisions of a RCRA Part B permit.   There is no known history of uncontrolled releases at these units. In addition, an integrity assessment is planned to demonstrate that the sulfuric acid neutralization tank system has no potential for causing releases. Therefore, these units were not included in the RFI.

The locations of the remaining seven SWMU's are shown in Figure 2-2.   A tabular summary of pertinent information for each unit, such as physical dimensions, period of use, possible hazardous constituents, etc. is provided in Table 5-2.

Materials that have been deposited at the Sodium Plant property include cell bath waste, anode butts, and miscellaneous solid waste including electrolytic cell construction materials and salt dissolver sludge.   Crude estimates of the quantities disposed on site, according to RMI records, are:

- 40,000 to 60,000 tons of cell bath waste
- 1,000 to 1,600 tons of anode butts
- 75,000 tons of miscellaneous solid waste
- 16,000 cu yd of salt dissolver sludge

TABLE 5-1

SWMU's IDENTIFIED AT THE
RMI SODIUM PLANT
ASHTABULA, OHIO

Previous SWMU's

- Closed Landfill[a]
- Fill Area North of Wastewater Treatment Ponds[a]
- Fill Area West of Wastewater Treatment Ponds
- Fill Area Northeast of Closed Landfill
- Fill Area Northwest of Closed Landfill
- Former Fill Area in the Vicinity of the Wastewater Treatment Ponds

Active SWMU's

- Five Wastewater Treatment Ponds[a,b]
- South Chute Waste Pile[c]
- Burning Room[c]
- Sulfuric Acid Neutralization System[a,b,c]

Other Unit Operations[d]

- Abandoned Pond East of Closed Landfill[a]
- East and West Brine Ponds
- Ashco Reservoir

[a]Listed in RCRA Permit.
[b]Part of RMI's NPDES treatment system.
[c]Because of containment features and no history of releases, these units have not been investigated as part of the RFI.
[d]Units are not defined as SWMU's under current RCRA regulations and policy (not investigated as part of the RFI).

TABLE 5-2

PROFILE OF PREVIOUS AND EXISTING SOLID WASTE MANAGEMENT UNITS[a]

Map Code	Name	Approx. Dimensions	Status	Period of Use	Potenital Hazardous Constituents	Other Information
A	Closed landfill	400 ft x 700 ft	Closed	1950 to 1980	barium, cadmium, lead	Closed in 1981; 2 ft clay cap
B	Fill area north-east of closed landfill	50 ft x 100 ft	Inactive	1950 to 1981	barium, cadmium, lead	Wastes reportedly removed to landfill during closure in 1981
C	Fill area north-west of closed landfill	150 ft x 200 ft	Inactive	1960s to 1981	barium, cadmium, lead	Wastes reportedly removed to landfill during closure in 1981
D	Former fill areas in vicinity of wastewater treatment ponds	#1 @ 150 ft x 300 ft #2 @ 80 ft x 120 ft #3 @ 60 ft x 175 ft	Inactive	1950s to 1960s	barium, cadmium, lead	Fill area encompassed area now occupied by Pond Nos. 2, 3, 4, 5; excavated wastes placed in fill areas north of ponds during pond construction; filled low areas
E	Wastewater Treatment Ponds[b]					Perimeter french drain installed in 1980
	Pond No. 1	100 ft x 400 ft (1.7 mil gal)	Active	1950 to present	chromium, lead, selenium silver	
	Pond No. 2	40 ft x 500 ft (1.4 mil gal)	Active	1956 to present	chromium, lead, selenium silver	
	Pond No. 3	170 ft x 170 ft (1.5 mil gal)	Active	1967 to present	chromium, lead, selenium, silver	
	Pond No. 4	170 ft x 200 ft (1.3 mil gal)	Active	1971 to present	chromium, lead, selenium, silver	
	Pond No. 5	150 ft x 150 ft (1.5 mil gal)	Active	1971 to present	chromium, lead, selenium, silver	
F	Fill areas west of wastewater treatment ponds	200 ft x 500 ft (overall)	Inactive	1966 to 1967	barium, cadmium, lead	Filled low areas
G	Fill area north of wastewater treatment ponds	200 ft x 300 ft	Inactive	1956 to 1976	barium, cadmium, lead	Received excavated materials from present site of wastewater treatment ponds during pond construction; filled low areas

[a]The two active hazardous waste management units for which RMI holds a RCRA operating permit, the South Chute Waste Pile and the Burning Room, are not included in this listing. The sulfuric acid neutralization system, part of RMI's NPDES treatment system (OEPA Permit No 3IE00012*AD), has also been excluded from this listing.

Waste piles were used from 1950 to 1981 for the disposal of solid wastes including brick, rubble, salt dissolver wastes, anode butts, and cell bath wastes. The salt dissolver wastes were generated from crude salt dissolving operations and consisted of rocks, dirt, salt, and debris. The waste piles were subsequently moved to on site landfill areas and, in some places, covered.

During August and September 1986, RMI collected several environmental samples at locations associated with or adjacent to active or previous SWMUs. These samples were analyzed by ECKENFELDER INC.'s laboratory for the eight Primary Drinking Water Standard (PDWS) metals, and in some cases, EP toxicity tests were performed. This work was initiated by RMI in preparation for the investigation, especially in consideration of defining appropriate analytical methods for the high salinity sample matrices at the plant. Comparative analytical results were transmitted to and discussed with USEPA and Ohio EPA, including quality assurance results, composition of standard reference solutions, etc.

Analytical summary tables, all of which have been previously transmitted to the agencies, are included in Appendix 7 for ease of reference, along with sample descriptions and a sample location map. These data will be referred to in the following discussions of previous and active SWMUs.

5.2.1 Previous SWMU's

5.2.1.1 **Closed Landfill.** There is one closed landfill at the Sodium Plant site. The landfill was active from 1950 to 1980 and received a variety of inorganic materials, including construction debris. Hazardous materials which were placed in the landfill include cell bath waste (EP toxic for barium, and possibly, cadmium and lead) and anode butts which contain hazardous constituents (lead and cadmium) but are not EP toxic under existing regulations and laboratory extraction procedures. Fill material may extend to

15 ft below ground surface. The landfill was closed in 1981 under a closure plan, which called for capping with 2 ft of clay followed by a grass cover. The DS tributary, which originally traversed the site, was rerouted to the west during landfill closure to reduce the potential for water infiltration into the landfill.

A limited subsurface site investigation and ground water monitoring evaluation at the landfill was conducted by Herron Consultants in 1980. The purpose of these investigations was to determine the stratigraphic sequence of the geologic formations at specific locations within the boundary of the Sodium Plant, determine the nature and level of contamination of groundwater in the vicinity of the landfill, and to determine the direction of groundwater flow and the flow gradient. These investigations included the installation of four wells, which were subsequently abandoned by grouting during the closure of the landfill area. The wells included a long sand-pack section which could have served as a pathway of downward contaminant migration. Groundwater flow direction was found by Herron to vary from southwest to northwest. Water-quality samples contained elevated levels of chromium; however, these results likely were influenced by a false positive interference due to high TDS concentrations. Hydraulic conductivity in the silts and clays of the glacial till was calculated at 10^{-5} to 10^{-7} cm/sec.

On September 30, 1981, leachate was observed in the ditch south of the closed on-site landfill. The observation was made by Mr. Larry Hanek and Mr. Joseph Holman of RMI Company and Chris Khourey, Gary Gifford, and Melinda Merryfield-Becker of the Ohio EPA. Several pools of a dark red liquid in the bottom sediments of the drainage ditch were reported. A strong odor likened to chlorinated organics was present in the area. This sighting was reported in a letter from Melinda Merryfield-Becker to J. T. Holman dated October 15, 1981. No conclusion as to the ultimate source of this apparent leachate was made. Analysis of samples taken indicated the presence of chlorinated organics and the analytical report is included in Appendix 7. Since RMI has not used chlorinated organics at the Sodium Plant, it is presumed that the chemicals migrated from an off-site source.

On June 26, 1986, after a severe 100-yr rain storm, leachate was observed seeping from the closed landfill site. A red-colored liquid was observed on the eastern side of the landfill. No odor was present. Leachate ceased within a relatively short period of time. The clay cap was repaired. These observations were made by Mr. Ben A. DiRienzo, Plant Manager; Mr. Joseph T. Holman, Manager - Environmental Control; Mr. B. J. Baughman, Manager - Engineering; Ms. Francine Norling, U.S. EPA Region V; and Ms. Christine Frazier, Ohio EPA.

The liquid sampled in 1986 and the liquid sampled in 1981 are not believed to have any chemical similarity. The samples collected in 1986 were obtained from the eastern side of the landfill and had no odor; samples collected in 1981 were from the ditch south of the landfill and had a strong organic odor. The materials also had significantly different appearances. Analyses of the sample collected in 1981 (see Appendix 7) revealed that it contained trichloroethylene (1.4 percent), tetrachloroethylene (1.0 percent), and tetrachloroethane (29.3 percent). The dark red liquid observed in 1981 is believed to be the result of migration of chlorinated solvents from an off site source. The red-colored liquid observed in 1986 appeared to be the result of oxidation of inorganics placed in the landfill.

In August/September 1986, three surface water samples were collected adjacent to the closed landfill (No. 1, No. 2, No. 13) along with one leachate sample (No. 6) from the east side of the landfill (see Appendix 7). These samples were analyzed for inorganics (it was known that only inorganics had been used or produced the Sodium Plant and the appearance and odor of the samples caused no reason to suspect organic compounds). Because it was suspected that high sodium chloride content in the samples would interfere with metals analyses, the samples were analyzed using several methods in order to develop an acceptable analytical method. Using the analytical methods appropriate to the sample matrices, none of the metals concentrations in these samples exceeded the PDWS values. In addition, only trace concentrations of several metals were detected in a surficial soil sample along the southern boundary of the landfill (No. B8-18), and the sample was not EP toxic (see Appendix 7).

5.2.1.2 **Fill Area North of Wastewater Treatment Ponds.** In the 1950s to 1960s, the site of the present wastewater treatment ponds was a low, marshy area which was used for the deposition of various plant wastes. These could have included cell bath waste, anode butts, construction debris, and Downs cell construction material. The approximate area that was used as a fill area is currently occupied by wastewater treatment Ponds Nos. 2, 3, 4, and 5. Pond No. 1 is believed to be outside the area where past disposal practices occurred.

The fill area north of the ponds received excavated materials from wastewater treatment Ponds Nos. 2, 3, 4, and 5 during their construction. It is believed, through interviews with senior and retired RMI personnel, that Pond No. 2 was excavated about 1956 to 1957. This excavated material was believed to have been deposited in this fill area. Pond No. 3 was excavated in 1967 and the debris from that construction is also believed to be placed in this fill area. Ponds No. 4 and 5 were excavated in 1976 and the debris is also believed to have been placed in this fill area. Because this area was a topographically low area before the deposition of wastes, wastes are likely to be present at some depth below the land surface.

5.2.1.3 **Fill Area West of Wastewater Treatment Ponds.** It is believed that in 1966 and 1967, cell bath waste was placed in this low lying fill area and covered.

5.2.1.4 **Fill Area Northeast of Closed Landfill.** As a result of interviews with senior and former RMI employees, it is thought to be possible that cell bath wastes and other wastes were deposited on the surface in this area. The earliest time period during which wastes were deposited on the surface of this fill area is estimated to be the 1950's. It is thought that these wastes were moved to the closed landfill in 1981 during landfill closure operations.

Water from the drainage ditch which traverses the approximate eastern boundary of this area was sampled and analyzed in August/September 1986 (sample No. 13) and did not contain metals in excess of PDWS values (see Appendix 7).

5.2.1.5 **Fill Area Northwest of Closed Landfill.** Also as a result of interviews with former and senior RMI employees, it is believed that some wastes, possibly including cell bath wastes, have been deposited on the surface in this area. The earliest time period during which wastes were deposited on the surface of this fill area is estimated to be the 1960's. It is also believed, as with the fill area northeast of the closed landfill, that these materials were removed to the landfill in 1981 and were enclosed during landfill closure operations.

5.2.1.6 **Former Fill Area in the Vicinity of the Wastewater Treatment Ponds.** The area that is now occupied by the wastewater treatment ponds was once a low marshy area. It is believed that the area was gradually filled with unknown plant waste materials to build up the elevation. This area was then excavated in three construction campaigns, beginning about 1956-57, for the construction of wastewater treatment ponds 2 through 5. It is unknown what materials other than native earth might have been excavated. It is also unknown what materials were originally deposited, although it is reasonable to assume they might have included cell bath waste, anode butts, and construction debris.

5.2.2 Active SWMU's

5.2.2.1 **Wastewater Treatment Ponds.** All of the wastewater treatment ponds are constructed within compacted clay. Pond No. 1 was originally a divided pond built in 1950. Today it is a undivided pond of approximately 1.7 mil gal volume. Pond No. 2 was built circa 1956 to 1957 and has a volume of 1.4 mil gal. Pond No. 3 was built in 1967 and has a volume of 1.5 mil gal. Pond No. 4 was built in 1971 and has a volume of 1.3 mil gal. Pond No. 5, also built in 1971, has a volume of 1.5 mil gal.

Pond No. 1 receives wastestreams containing hypochlorite and calcium sulfate. After sedimentation of suspended matter, the hypochlorite is treated (dechlorination) prior to discharge to Pond No. 3. Pond No. 2 receives wastestreams from the brine plant and cell parts washing. Pond Nos. 3, 4, and 5 receive, in sequence, the effluents from Pond Nos. 1 and 2. These ponds are collectively used to settle suspended solids from chlorine neutralization operations, sludge from sulfuric acid neutralization operations, brine treatment solids, and suspended material from other in-plant wastestreams. The effluent from the pond system (Pond No. 5 effluent) discharges to Fields Brook and is regulated under NPDES permit No. 3IE00012*AD reissued by Ohio EPA in May 1985. This permit requires weekly effluent monitoring for flow, total dissolved solids (TDS), total suspended solids (TSS), total residual chlorine (TRC), 5-day biological oxygen demand (BOD_5), and temperature, and prescribes discharge limitations for TSS and TRC.

In August 1988, acute toxicity tests were conducted on the final effluent from the RMI site. The tests were conducted using fathead minnows (Pimephales promelas) and water fleas (Ceriodaphnia dubia). There were no acute mortalities in the effluent tested with P. promelas and 45 percent mortality in tests using C. dubia. No LC_{50} values were calculated since 50 percent mortality was not observed in either test. Test results are contained in Appendix 8.

In September 1988, final effluent samples were tested for priority pollutants. None of the organic parameters included in the scan were detected in the effluent samples. In addition, none of the heavy metals tested were above method detection limits. These test results are also contained in Appendix 8.

The ponds are dredged periodically. The pond to be dredged is bypassed and the liquid portion is decanted to other ponds. The sludge is then removed by clamshell bucket and trucks for disposal at an approved landfill site. In 1981, the wastewater treatment pond sludge was tested for EP Toxicity. Test results (contained in Appendix 8) indicated that the sludge is not a hazardous waste.

In 1980 a french drain was installed around the perimeter of the five treatment ponds. The system consists of a deep trench, 7 ft deep and 14 in. wide, filled with No. 8 washed stone. The trench is covered by a 1 ft layer of compacted clay to ground surface. A 6 in. diameter perforated PVC pipe lies on the bottom of the trench to conduct the water collected in the trench. The purpose of the french drain system is to minimize the escape of water from the immediate vicinity of the ponds by providing a groundwater divide at the periphery of the wastewater treatment ponds. Pumps return collected liquids back to the pond system.

Three samples of the liquid collected in the french drain beneath the ponds were analyzed (No. 17, No. 18, No. 19) in August/September 1986, using the analytical methods appropriate to these highly saline sample matrices. Chromium, lead, selenium, and silver were detected in the samples, although none of the concentrations exceeded PDWS values. Cadmium was also detected and was found to exceed PDWS values on two occasions. A whitish surficial soil sample collected from a point to the east of the ponds (No. A8-18) was not EP toxic (reference Appendix 7).

5.2.2.2 **South Chute Waste Pile.** The South Chute Waste Pile receives only cell bath wastes consisting of overflow material from the Down's cells and wastes generated during cell maintenance. These wastes are sometimes EP toxic for barium, cadmium, and/or lead. The South Chute Waste Pile was constructed in 1981 to provide for the accumulation of cell bath waste prior to disposal off site. The material may remain there for three to five days until a full shipping load is accumulated. This waste pile is constructed of a concrete floor and concrete wall sections. The floor is covered with 1 in. thick checker-steel and the wall sections are covered with 0.5 in. plate steel. The waste pile bin is constructed so that no wastes are able to seep or leak from the structure. The bin is covered and enclosed with resolite roofing and siding material to prevent stormwater from entering the bin. The structure is three sided with an open entrance side to allow loading and unloading of cell bath wastes. The entry ramp is constructed of concrete covered with steel and

is elevated 7 in. in the center to prevent stormwater run-on and loss of wastes through the entrance ramp. The South Chute Waste Pile is currently in use and is an active, permitted hazardous waste management unit. Because suitable containment has been provided for the cell bath wastes, and because there is no history of release, this unit has not been included in the RFI.

5.2.2.3 **Burning Room.** Waste sodium/calcium solids are thermally treated in the Burning Room for the disposal of these materials. The Burning Room is an active, permitted hazardous waste management unit. This SWMU can process 125 lb/hr of sodium/calcium sludge, however, the unit is operated on a batch basis and only when sufficient processing quantities are accumulated. Burning of the reactive sodium/calcium sludge is accomplished in a 14 ft by 13 ft by 11 ft high enclosure using natural gas torches. This unit is equipped with exhaust and air pollution control equipment. The quantity of air entering the high energy venturi is maintained at 12,000 cu ft per minute during operation. Emissions from the burning room are regulated under the Clean Air Act. Off-gases resulting from this thermal treatment operation include primarily sodium and calcium oxides. For these reasons, and because there is no history of release, this unit has not been included in the RFI.

5.2.2.4 **Sulfuric Acid Neutralization System.** The sulfuric acid neutralization system consists of an above ground sulfuric acid storage tank and a concrete neutralization pit. This neutralization facility is discussed in the RCRA Part B application. In this unit, waste sulfuric acid from the chlorine pumping and chlorine liquefaction operations is neutralized. This waste is hazardous due solely to the characteristic of corrosivity. This unit is exempt from RCRA permitting requirements in accordance with 40 CFR 264.1(g)(6).

The neutralization system involves treatment in concrete tanks as part of the NPDES treatment system (OEPA Permit No. 3IE00012*AD) at the Sodium Plant. Because the neutralization is accomplished in suitable tanks, and there is no history of release, the sulfuric acid neutralization system has not been included in the RFI. However, as discussed on page 5-1, an integrity assessment is planned to demonstrate that the sulfuric acid neutralization tank system has no potential for causing releases.

5.2.3 Description of Selected Manufacturing Process Units

These unit operations, both existing and abandoned, are not defined as SWMUs under current RCRA regulations and policy as they have never contained waste materials. These units are addressed for purpose of clarification.

5.2.3.1 **Abandoned Pond East of Closed Landfill.** This surface impoundment is located immediately east of the closed landfill. This pond was constructed in 1956 and was used for holding leach brine pumped from Electromet (UCC). It was abandoned in 1957 to 1958 when the UCC plant was closed. This pond was also used as a holding pond for leach brine in 1981 while the No. 2 East Brine Pond was being constructed. This occurred during a six month period. Upon completion of the No. 2 brine pond, this pond was emptied of brine and abandoned. RMI's RCRA permit for the Sodium Plant mistakenly identified the abandoned pond east of the closed landfill as a potential SWMU at the facility. This pond was unfortunately again mistakenly identified in RMI's revised "Certification Regarding Potential Releases from Solid Waste Management Units" transmitted to USEPA and Ohio EPA in late September 1986. However, the abandoned pond has never contained known hazardous constituents and it has been confirmed that the abandoned pond is not a SWMU, based on RMI's CERCLA 104 Response.

5.2.3.2 **East and West Brine Ponds.** The two brine ponds, designated as the East Pond and the West Pond, are used for holding brine from the solution mining operations. The solution mining produces a fortified salt brine which is used as a Sodium Plant feed stock. The West Pond has a volume of 1,000,000 gal and was built in 1968. The East Brine Pond has a capacity of 1,000,000 gal and was built in 1981. Each pond is lined with a 41 mil Hypalon liner with a 10 by 10 polyester scrim and underdrain collection system. This underdrain collection system was installed in 1981. Although these ponds were unfortunately mistakenly identified in RMI's revised "Certification Regarding Potential Releases from Solid Waste Management Units" transmitted to USEPA and Ohio EPA in September 1986, these ponds have not been used for any other purpose and have never contained known hazardous constituents.

5.2.3.3 **Ashco Reservoir.** The Ashco Reservoir is an impoundment of approximately 7.5 mil gal volume which was constructed in 1957. Ashco was incorporated in the State of Ohio in 1949 as Ashco Industrial Water Company. The company was formed to supply raw lake water to plants owned by National Distilleries Corporation and Detrex Chemical Industries Inc. The impoundment has received raw lake water from Lake Erie and has not been used for any other purpose and has never contained known hazardous constituents.

5.3 WASTE CONSTITUENT CHARACTERIZATION

5.3.1 Identification of Waste Constituents

A summary of waste types received for each of the seven SWMU's investigated during the RFI is presented in Table 5-3. Also included is a listing of the hazardous constituents expected to be present in each of the SWMUs. Although not reported to be present in the plant wastes, arsenic, nickel, mercury, and zinc have been detected in some of the environmental samples collected as part of this RFI, and have the potential to be present in some of the wastes (see Section 6.0). Therefore, these parameters will be included in the following discussions on waste constituents.

In the closed landfill and former fill areas, wastes consist of cell bath wastes, anode butts, and construction debris. In these areas, barium, cadmium, and lead are suspected hazardous constituents. Barium is present in the cell bath and anode wastes because it is added to the sodium chloride process solution in order to precipitate barium sulfate, thereby taking the sulfate out of solution. Cadmium and lead are present in the fusible alloy base connectors for the carbon anodes in the Downs cells and then concentrate in the cell bath.

The wastewater treatment ponds contain trace amounts of chromium, lead, selenium, and silver. These elements are probably naturally occurring in the raw materials used in the manufacturing process or may also result from corrosion of process equipment.

5-13

TABLE 5-3

WASTE CHARACTERIZATION OF SWMU'S

Map Code	SWMU	Waste Type Received	Physical State of Waste	Potential Hazardous Constituents
A	Closed Landfill	Cell bath waste Anode butts	Solid	Barium, cadmium, lead
B	Fill Are Northeast of Closed Landfill	Cell bath waste Unknown wastes	Solid or Unknown	Barium, cadmium, lead
C	Fill Area Northwest of Closed Landfill	Cell bath waste Unknown wastes	Solid or Unknown	Barium, cadmium, lead
D	Former Fill Areas in Vicinity of Wastewater Treatment Ponds	Unknown wastes Likely cell bath waste, anode butts, construction debris, salt dissolver sludge	Solid or Unknown	Barium, cadmium, lead
E	Wastewater Treatment Ponds			
	Pond No. 1	Wastestreams containing hypochlorite and calcium sulfate	Liquid	Chromium, lead, selenium, and silver
	Pond No.2	Wastestreams from brine plant and cell parts washing	Liquid	Chromium, lead, selenium, and silver
	Pond Nos. 3, 4, 5	Effluents from Pond Nos. 1 and 2	Liquid	Chromium, lead, selenium, and silver
F	Fill Area West of Wastewater Treatment Ponds	Cell bath waste Salt dissolver sludge	Solid	Barium, cadmium, lead
G	Fill Area North of Wastewater Treatment Ponds	Cell bath waste Anode butts Construction debris Downs cell construction material Excavated materials from construction of wastewater treatment Ponds Nos. 2, 3, 4, and 5 Salt dissolver sludge	Solid	Barium, cadmium, lead

[a]As discussed in Section 6.0, arsenic, mercury, nickel, and zinc have been detected in some environmental samples. Therefore, these elements will be considered as potential hazardous constituents.

5.3.2 Chemical and Physical Properties of Waste Constituents

Available data on the physical and chemical properties of the waste constituents are presented in Table 5-4. Several of the properties listed in RFI guidance documents (e.g., Henry's Law Constant, octanol/water coefficient) are not applicable to the metals present at the RMI Sodium Plant, and therefore, are not provided.

5.3.3 Aquatic Behavior of Waste Constituents

The following discussion is summarized from "Water-Related Environmental Fate of 129 Priority Pollutants" (EPA-440/4-79-029a) published by the USEPA in December 1979. Information was available in this publication for arsenic, cadmium, chromium, lead, mercury, nickel, selenium, silver, and zinc. As summarized in Table 5-5 and discussed below, three processes are most important in the aquatic fate of the metals of concern: chemical speciation, sorption, and bioaccumulation. In addition, biotransformation is a significant process in the environmental fate of arsenic, lead, mercury, and selenium. Photolysis of lead and mercury compounds and volatilization of arsenic, mercury, and selenium may also be significant.

Information on barium was summarized from Environmental Inorganic Chemistry, (Bodek, et al. (eds.) 1988). Although little data are available on the aquatic behavior of barium, this source of information indicates that chemical speciation and sorption are important processes in the aquatic behavior of barium.

5.3.3.1 Chemical Speciation. Chemical speciation of metals occurs as the result of oxidation/reduction, hydrolysis, or other reactions, and alters the properties of a given chemical.

TABLE 5-4

PHYSICAL AND CHEMICAL PROPERTIES OF WASTE CONSTITUENTS

	Molecular Weight (g/mole)	Boiling Point[b] (°C)	Melting Point[b] (°C)	Density[b]	Vapor Pressure[b] (mm Hg)	Solubility[b] (mg/l)
Arsenic	75	613	817	5.73 @ 14°C	1 @ 372°C	Insoluble in water
Barium	137	1,640	725	3.51 @ 20°C	10 @ 1,049°C	ND[c]
Cadmium	112	765	321	8.65 @ 25°C	1 @ 394°C	Insoluble in water
Chromium	52	2,642	1,900	7.14	1 @ 1,616°C	Insoluble in water
Lead	207	1,740	327.4	11.34 @ 20°C	1.77 @ 1,000°C	Insoluble in water
Mercury	200	357	-38.9	13.53 @ 25°C	0.002 @ 25°C	0.28 μmoles/l
Nickel	59	2,730	1,455	8.90	1 @ 1,810°C	Insoluble in water
Selenium	79	690	170-217	4.26-4.81	>0.001 @ 20°C	Insoluble in water
Silver	108	~2,000	960.5	10.49 @ 15°C	ND	Insoluble in water
Zinc	65	908	419.5	7.14 @ 25°C	1 @ 487°C	Insoluble in water

[a]USEPA, October 1986b. "Superfund Public Health Evaluation Manual", Office of Emergency and Remedial Response.
[b]TOXNET (TOXicology data NETwork), the National Library of Medicine, Bethesda, MD.
[c]ND = no data found.

TABLE 5-5

SUMMARY OF AQUATIC FATE OF METALS OF CONCERN[a]

| Waste Constituent | Environmental Process[b] | | | | | |
	Photolysis	Chemical Speciation	Volatilization	Sorption	Bioaccumulation	Biotransformation
Arsenic	Insignificant (Medium)	Significant (High)	Significant (High)	Significant (High)	Significant (Medium)	Significant (High)
Barium	Insignificant	Significant	Insignificant	Significant	Insignificant	Insignificant
Cadmium	Insignificant (High)	Significant (Medium)	Insignificant (High)	Significant (High)	Significant (High)	Insignificant (Medium)
Chromium	Insignificant (Medium)	Significant (Medium)	Insignificant (Medium)	Significant (Medium)	Significant (High)	Insignificant (Low)
Lead	Significant (Medium)	Significant (Medium)	Insignificant (Medium)	Significant (High)	Significant (High)	Significant (Medium)
Mercury	Significant (Medium)	Significant (High)	Significant (High)	Significant (High)	Significant (High)	Significant (High)
Nickel	Insignificant (Medium)	Significant (Medium)	Insignificant (Medium)	Significant (High)	Insignificant (Medium)	Insignificant (Medium)
Selenium	Insignificant (Low)	Significant (Medium)	Significant (Medium)	Significant (Medium)	Significant (Medium)	Significant (Medium)
Silver	Insignificant (Low)	Significant (Medium)	Insignificant (Medium)	Significant (High)	Significant (High)	Insignificant (Medium)
Zinc	Insignificant (Medium)	Significant (Medium)	Insignificant (Medium)	Significant (High)	Significant (High)	Insignificant (Medium)

[a]Barium is not included in the source document. However, information contained in Environmental Inorganic Chemistry, 1988 (I. Bodek, et al., eds.) indicates that chemical specification and sorption are important processes in the aquatic fate of barium.

[b]Level of confidence of data is indicated in parentheses.

Source: USEPA, 1979, "Water-Related Environmental Fate of 129 Priority Pollutants".

Arsenic.   In aquatic systems, arsenic has an unusually complex chemistry.   Arsenic is stable in four oxidation states (+5, +3, 0, -3) under Eh conditions occurring in aquatic systems.   Arsenic metal occurs only rarely and the -3 oxidation state is stable only at extremely low Eh values.   Because of its multiple oxidation states and its tendency to form soluble complexes, the chemistry of arsenic is intricate and not well characterized.

The speciation of arsenic in natural waters is significantly influenced by biota.   Arsenic and methylated arsenic have been positively correlated with biological activity.   In waters below the euphotic zone, arsenic concentrations increase with depth and remain in solution.

Levels of dissolved arsenic in fresh water may be controlled by the availability of arsenic, rain water dilution, the extent of complexation with dissolved organic matter, and by the metabolic activity of plants.

Barium.   Chemical speciation is important under environmental conditions for the Ba^{+2} oxidation state.   In aqueous environments containing chloride (Cl^-), sulfate (SO_4^{-2}), nitrate (NO_3^-), and carbonate (CO_3^{-2}) anions (at pH less than or equal to 9.3), Ba^{+2} is the dominant species.   In waters with high sulfate concentration, appreciable levels of $BaSO_4$ occur.   In the presence of carbonate at pH greater than 9.3, $BaCO_3$ is an important species.

Ba^{+2} forms relatively weak complexes with Cl^-, hydroxide (OH^-), and NO_3^-. Barium forms complexes with natural organics to a limited extent.

Barium sulfate has very low solubility and may limit barium concentrations in natural water at pH less than or equal to 9.3.   At pH greater than 9.3, barium carbonate (also of low solubility) may control the concentration.

Cadmium.   The transport of cadmium in the aquatic environment is controlled by the speciation of the ion.   In most aquatic environments, cadmium will exist mainly as the hydrated divalent cation (Cd^{+2}) in a pH

environment to about 9. However, in waters high in organic content, complexation with organic material will be most important. That is, the presence of organic material will have a large effect on the chemical form in which cadmium will be present, and serves to increase the concentration of cadmium in solution. In most fresh water systems, the cadmium will form bonds with the following ligands in the following order of magnitude of affinity: humic acids, CO_3^{-2}, OH^-, Cl^-, SO_4^{-2}.

Chromium. Chromium occurs in valence states ranging from $^-2$ to $^+6$. The most important forms that occur in aqueous environments are trivalent chromium (Cr^{+3}) and hexavalent chromium (Cr^{+6}).

Trivalent chromium is the most stable form under redox conditions normally found in natural waters and sediments. When in solution at a pH greater than 5, it quickly forms an insoluble hydroxide or oxide.

Hexavalent chromium is important in environmental and biological systems because of its high toxicity. It is a strong oxidizing agent and is always found in aqueous solution as a component of a complex anion. Anionic forms vary with pH, but in most natural waters (pH>6.5) the chromate ion (CrO_4^{-2}) will be present. Dichromate ($Cr_2O_7^{-2}$) concentrations will be significant in low pH waters. All anionic forms are quite soluble and mobile in the aquatic environment.

Therefore, if aquatic conditions favor hexavalent chromium, then chromium will accumulate as soluble forms in water. If trivalent chromium is favored, accumulation of chromium will occur in sediments.

Lead. Throughout most of the natural environment, the divalent form of lead (Pb^{+2}) is the stable ionic species of lead. However, lead has a strong tendency to form complexes of low solubility with the major anions of natural systems. Over most of the normal pH range, $PbCO_3$ and $PbSO_4$ control solubility in aerobic conditions while PbS and Pb^O control solubility in

anaerobic conditions. However, the amount of organic material present will have a great effect on the chemical form in which lead will be present and organics can serve to increase the amount of lead in solution..

Mercury. Under normal conditions of temperature and pressure that occur in the aquatic environment, mercury can be present in any one of three oxidation states: Hg^{+1}, Hg^{+2}, and Hg^0.

Within a moderately oxidizing environment above pH 5, the predominant mercury species will be elemental mercury. Mildly reducing conditions (which may occur in sediments) can cause mercury to be precipitated as the sulfide cinnabar, which has an extremely low aqueous solubility. In aquatic environments that are high in chloride, the solubility of mercury in oxygenated solutions may be greatly increased by the formation of charged mercuric (Hg^{+2}) chloride complexes.

Mercury also exhibits an affinity for sulfhydryl groups (^-SH) and organic amino groups which are present in proteins, amino acids, and their derivatives. Methyl mercuric chloride (CH_3HgCl), which is water soluble, and dimethyl mercury (CH_3HgCH_3), which is insoluble in water, may also form in the environment.

Nickel. Nickel is almost always found in the divalent oxidation state in aquatic systems. Under reducing conditions and in the presence of sulfur, the insoluble sulfide is formed. Under aerobic conditions with pH below 9, nickel forms soluble compounds with OH^-, CO_3^{-2}, SO_4^{-2} and naturally occurring organic ligands. Above pH 9, precipitation of the hydroxide or carbonate exhibits some control on nickel mobility.

Humic acids in natural waters alter the solubility and precipitation behavior of nickel. Humic acids may increase the solubility of nickel under natural conditions to the point that precipitation is probably not a significant fate.

Selenium. The chemical speciation of selenium controls solubility. Under anaerobic conditions and/or low pH, insoluble elemental selenium is formed. Under other conditions, soluble complexes are formed.

Silver. Chloride, bromide, and iodide ions control the levels of hydrated silver cations in the environment. Crystalline, metallic silver, and silver sulfides may precipitate under reducing conditions.

Zinc. Zinc has an oxidation state of +2 in aqueous systems. In most natural waters, zinc will exist mainly as a divalent cation and will be easily adsorbed. In waters with large amounts of organic material, complexation will dominate. Precipitation of zinc compounds appears to be important only in reducing environments.

5.3.3.2 Sorption. The sorption of chemicals to suspended or bottom sediments occurs when ions are attracted to the strong surface forces associated with particulates of very small size.

Arsenic. Cycling of arsenic in the aquatic environment is dominated by adsorption and desorption to sediments. Arsenic may be sorbed onto clays, aluminum hydroxide, iron oxides, and organic material. Under most conditions, coprecipitation or sorption of arsenic with hydrous oxides of iron is probably the prevalent process in the removal of dissolved arsenic. Adsorption will be most important in aerobic, acidic, fresh waters. As conditions become more reducing, alkaline, and/or saline, arsenic is less likely to be adsorbed and more likely to remain dissolved.

Barium. Sorption of barium to soils or sediments occurs onto metal oxides and hydroxides. Adsorption onto metal oxides probably acts as a control over the concentration of barium in natural waters. Complexation by soil organic material occurs to a limited extent.

Cadmium. Sorption processes reduce the mobility of cadmium in the aquatic environment and result in the enrichment of suspended and bed sediments relative to the water column. In natural waters, sorption onto clay minerals and hydrous iron and manganese oxides are controlling factors. Where organic materials are present, sorption onto organic materials is the controlling factor. Sorption processes, in either case, are important in determining cadmium transport, partitioning, and potential for remobilization.

Chromium. Trivalent and hexavalent chromium are only weakly adsorbed onto organic solids. Adsorption of both forms by clay minerals is affected by pH. Adsorption of hexavalent chromium decreases as pH increases and $HCrO_4^-$ is the dominant species adsorbed. Adsorption of trivalent chromium increases as pH increases and it may be 30 to 300 times more strongly sorbed than hexavalent chromium. Consequently, hexavalent chromium tends to be highly mobile while trivalent chromium tends to be quickly immobilized into sediments.

Lead. Sorption processes appear to exert a dominant effect on the distribution of lead in the environment. Adsorption of lead to soils and oxides is highly pH-dependent, but above pH 7, essentially all of the lead is in the solid phase. At a low pH, lead is repelled from the adsorbent surface. Organic complexing agents increase the affinity of lead for adsorption. In general, adsorption to inorganic solids, organic materials, and hydrous iron and manganese oxides usually controls the mobility of lead.

Mercury. Sorption processes result in the strong partitioning of mercury into suspended and bed sediments. Sorption rates increase with increasing organic content and are little affected by pH. Adsorption of inorganic mercury is affected by aquatic chloride concentrations with the amount of loss of absorption capacity depending upon the constituents of the sediments. Mercury adsorption onto sediments is probably the most important process for determining the fate of mercury in the aquatic environment.

Nickel.   Sorption of nickel by hydrous iron and manganese oxides and organic material exerts the major control on the mobility of nickel in the aquatic environment.   However, nickel is a highly mobile metal and is sorbed only to a small extent.   The partitioning of nickel into dissolved and particulate fractions is related to the abundance of suspended material, competition with organic material and concentrations of iron and manganese. Coprecipitating hydrous iron oxides probably attract nickel more strongly than organic material.   Ion exchange with crystalline minerals may also affect nickel mobility.

Selenium.   Selenium is sorbed most strongly by hydrous iron and manganese oxides and to a lesser extent by clays and organic materials.   The hydrous metal oxides usually comprise a smaller proportion of suspended solids than do clays and, consequently, most of the selenium in aquatic systems is probably transported as the dissolved species.   Studies also suggest that adsorption of selenium is pH-dependent and that selenium may be quite mobile in clays, especially under alkaline conditions.   Only in areas of high hydrous iron and manganese oxide concentrations will selenium be sorbed into bed sediments.

Silver.   Silver is also strongly sorbed by hydrous iron and manganese oxides as wells as clay minerals and organics.   Sorption is a major controlling mechanism in determining the fate of silver in the aquatic environment.

Zinc.   Sorption of zinc by hydrous metal oxides, clay minerals, and organic materials is probably the dominant fate process for zinc in aquatic environments.   Coprecipitation and sorption of dissolved zinc by the hydrous metal oxides are especially important where high concentrations of reduced iron and manganese are present in aerobic surface waters.   Zinc may be sorbed onto dissolved or suspended solids and colloidal or suspended organic matter. Zinc adsorption increases with pH; below pH 6, little or no zinc may be adsorbed.   Zinc is desorbed from sediments as salinity increases.

5.3.3.3 **Bioaccumulation**. Bioaccumulation is most important with hydrophobic chemicals which can be partitioned into fat and lipid tissues. It is measured by a bioconcentration factor, usually defined as the concentration of a chemical in tissue divided by the concentration in water.

Arsenic. Although arsenic is toxic, it is bioaccumulated. Arsenic is accumulated by fish both from water and from food, but reported concentration factors for arsenic in aquatic organisms is generally low (Table 5-6). Arsenic compounds do not show a tendency to biomagnify.

In general, arsenic accumulates in fat tissues more readily than other types of tissue. Shell fish concentrate arsenic to a much greater extent than fish, and marine organisms contain more arsenic than freshwater species. High toxicity lowers overall accumulation by aquatic organisms.

Cadmium. Cadmium is strongly accumulated by all organisms. Because it is chemically similar to zinc, it may displace zinc in certain enzymes and disrupt normal metabolic function. Cadmium has been reported to accumulate in the tissues of aquatic and marine organisms at concentrations hundreds to thousands of times higher than that in the water column. Bioaccumulation is greater in soft than in hard water and uptake increases with increasing water temperature and decreasing salinity. Bioconcentration factors for cadmium are summarized in Table 5-6.

Chromium. Chromium is an essential nutrient and is accumulated in aquatic and marine biota to levels much higher than in ambient water. However, levels in biota are usually lower than in sediment. Chromium may be transferred through the food chain, but concentrations decline as trophic level increases. Bioconcentration factors for chromium as listed in Table 5-6.

Lead. Lead is also bioaccumulated by aquatic organisms. However, microcosm studies indicate that lead is not food-chain biomagnified. Decreasing pH increases the availability of divalent lead, the principal form accumulated by aquatic animals. Bioconcentration factors for lead are summarized in Table 5-6.

TABLE 5-6

BIOCONCENTRATION FACTORS FOR WASTE CONSTITUENTS

Taxon	Concentration Factor[a]								
	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver	Zinc
Freshwater Plants	333	ND[b]	1,000	4,000	200	1,000	800	200	4,000
Freshwater Invertebrates	333	ND	4,000	2,000	200	100,000	400	3,080	40,000
Freshwater Fish	333	ND	3,000	200	60	1,000	400	3,080	1,000

[a]Bioconcentration factors are the ratio derived from the concentration of the element in the aquatic organism (in ppm wet weight) divided by the concentration of the element in water (in ppm).

[b]ND = No data found.

Source: USEPA, December 1979. "Water-Related Environmental Fate of 129 Priority Pollutants".

Mercury. Methyl mercury is the form of mercury most readily accumulated and retained by aquatic biota. Bacteria common to most natural waters are capable of converting many mercury compounds to methyl mercury. Therefore, mercury compounds entering the water may become a bioaccumulated hazard if environmental conditions are favorable for biomethylation.

Methyl mercury is readily accumulated by fish from both their food and through the water. The half-life of methyl mercury in aquatic organisms is between one and three years. Bioconcentration factors for mercury are shown in Table 5-6.

Selenium. Available data indicate that while dietary selenium is the most important source of selenium to many marine and freshwater organisms, little food-chain biomagnification takes place. In some instances, the accumulation of selenium by organisms may be beneficial as selenium inhibits the accumulation of mercury. Because of selenium's high toxicity, the relationship between selenium toxicity to aquatic organisms and selenium beneficial accumulation is uncertain. Bioconcentration factors for selenium are summarized in Table 5-6.

Silver. Silver bioaccumulation is primarily a function of sorption/desorption from sediments. Although numerous plants and organisms accumulate silver, it is not present in aquatic life at very high concentrations because most silver compounds are sparingly soluble in water. Although silver is one of the metals most toxic to animal life, there is little apparent food-chain magnification. Silver also has a very short biological half-life. Bioconcentration factors for silver are contained in Table 5-6.

Zinc. Bioaccumulation of zinc occurs in all organisms. It is not biomagnified. Bioaccumulation occurs even in the absence of abnormally high zinc concentrations since it is an essential nutrient. Zinc is readily accumulated by both marine and freshwater fish from both food and water, but

internal organs and bones accumulate much high zinc levels than edible muscle tissue. While zinc is actively bioaccumulated, the biota appear to represent a relatively minor sink when compared to sediments. Bioconcentration factors for zinc are provided in Table 5-6.

5.3.3.4 **Biotransformation.** Biotransformation results from enzyme-catalyzed transformation of chemicals. It may be a significant process in the case of arsenic, lead, mercury, and selenium.

Arsenic may undergo a number of biological transformations in aquatic environments, most of which involve methylation to derivatives of arsine (AsH_3). Arsenic forms stable bonds with sulfur and carbon in organic compounds. Arsenic is metabolized by a number of organisms to organic arsenicals, thereby increasing arsenic mobility in the environment.

Lead may be methylated by microorganisms in lake sediments. The volatile compound resulting from biomethylation (tetramethyl lead) probably leaves the sediments and is either oxidized in the water column or enters the atmosphere. In addition, ligands can be significant in the complexing of lead and may have a significant impact on the aquatic fate of lead.

Mercury can be metabolized by bacteria to methyl and dimethyl forms which are quite mobile in the environment. Biomethylation of mercury in the sediments can result in remobilization. Conditions reported to enhance the methylation process include large amounts of available mercury, large numbers of bacteria, the absence of strong complexing agents such as sulfide, neutral pH, high temperature, and a moderately aerobic environment. Demethylation processes can occur but only when methyl mercury levels become excessive.

Selenium may also be methylated with subsequent volatilization. Studies on the biotransformation of selenium have only included terrestrial plants and animals, but extrapolation to the aquatic environment is probably valid.

5.3.3.5 **Photolysis.** Photolysis occurs when a chemical absorbs light and subsequently undergoes a transformation reaction. Of the chemicals of concern, only in the cases of lead and mercury compounds is photolysis an important process.

Although there is no evidence concerning the photolysis of lead compounds in natural waters, photolysis of lead compounds in the atmosphere is a controlling factor on the form of lead that will enter the aquatic environment. The ultimate products of photolysis of lead compounds in the atmosphere are lead oxide and the halogens. The importance of photolysis within natural waters is undeterminable.

Photolysis may be of significance to the chemical speciation of mercury in the atmosphere and possibly in the aquatic environment. Dimethyl mercury in the atmosphere may break down to methyl mercury by photolysis. Photo decomposition of phenyl mercury compounds in both the atmosphere and natural may also occur. It is not clear what impact photolysis may have on the overall fate of mercury in the aquatic environment.

5.3.3.6 **Volatilization.** Volatilization from water to the atmosphere is especially important for chemicals with high vapor pressures or low solubilities. Of the metals in question, volatilization may be significant for arsenic, mercury, and selenium.

Volatilization of arsenic may be a significant process in extremely reducing environments where arsine (AsH_3) is formed, but under normal circumstances, it is not an important mechanisms in determining the fate of arsenic in an aquatic environment. Methylated arsenic derivations may also have potential for volatilization.

Metallic mercury has a uniquely high vapor pressure relative to other metals and can enter the atmosphere from the aquatic environment as several different gaseous compounds. Microbial methylation of mercury is expected to enhance

the evaporation loss of mercury. The rate of vaporization of mercury and some of its inorganic compounds decreases in the sequence Hg, Hg_2Cl_2, $HgCl_2$, HgS, and HgO.

Methylation of selenium occurs in plants and organisms producing volatile compounds which may escape to the atmosphere. Volatile selenium can also be formed by inorganic means. For example, H_2Se can be formed under reducing conditions.

5.3.4 **Behavior of Waste Constituents in Soils.** The mobility of an element in the soil is directly affected by fixation and adsorption of the element to the soil, the thermodynamic stability of complexes and minerals formed, and the kinetics of the reactions involved, all of which can be influenced by the physical and chemical properties of the soil. The mobility of any given element is therefore, to a large extent, a function of the characteristics of the soil in which it is located. Water hardness and salinity also influence mobility by affecting speciation, or the chemical form that the element takes.

Soil characteristics that can influence mobility of metals and other chemical species include texture, clay and oxide content, pH, cation exchange capacity, density, and porosity, but there are general trends related to soil texture that can be identified.

In general, cations have low mobility in clay and silty clay soils, and moderate to high mobility in sandy, loamy sand, and sandy loam soils. For soils of intermediate texture, cations will generally have higher mobility in soils with low pH than those with high pH.

Anions generally have low mobility in clay and silty clay soils and moderate to high mobility in loamy and sandy soils and usually exhibit increasing mobility with increasing pH (Dragun, 1988).

The metals of concern for the purposes of this report are arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, silver, and zinc. The mobility of each in the soil will be considered separately.